

# Testing average then retrieve approach with PCRTM with CALIPSO/CloudSat clouds

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# Objective of this work

- Test temperature and water vapor retrievals with a finer vertical resolution using all-sky spectral radiances
  - 15 layers (16 layer boundaries): 0.005, 10, 50, 100, 200, 300, 400, 500, 600, 700, 800, 850, 900, 950, 1000, 1100 hPa
- Evaluate retrieval results quantitatively
  - Nadir view sampling error vs. retrieval error
- Test retrievals with AIRS data (16 day mean nadir view spectral radiances)

# Spectral radiance computation

- C3M (CALIPSO, CloudSat, and MODIS derived cloud fields)
- MERRA (T and Q)
- Nadir view spectral radiance and Jacobians by PCRTM
- Sampling is the same as nadir view AIRS spectral radiance

# Main Elements

- PCRTM over AIRS channels, thermal IR only
  - 2378 channels ( 649-1613 / 2181-2665 cm<sup>-1</sup>)
- CALIPSO, CloudSat, CERES, MODIS (C3M) data product
  - near nadir FOVs
  - cloud properties: fraction, tau, height, phase, Re/De
- GMAO MERRA assimilation
  - ( 0.66 deg x 0.50 deg x 72 levels)
  - Temperature , Humidity , Ozone profiles
  - Skin Temperature
- IASI-derived surface emissivity (Zhou et al. 2013) for 18 IGBP types at PCRTM 493 monochromatic wavenumbers

# Additional Details

- Up to 4 (Clear, Low, Mid , High) cloud columns per FOV
  - Cloud fraction weighted average for the FOV total-sky spectral radiance.
- Jacobians for each sub-FOV scale cloud column (43 total Jacobians):
  - Temperature and Humidity 15 levels ( $15 \times 2$ )
  - Skin temperature
  - Cloud : Fraction , Pressure, Cloud Tau , Particle Size ( $4 \times 3$ )
- Computation for a nadir view angle made for slightly (< 15deg) off-nadir FOV atmosphere properties from C3M.
- Gridding to 2.5x2.0 deg grid, individually averaged for ascending and descending over 16 day period to match gridded AIRS nadir radiance product provided by X. Huang.
  - Gridded AIRS from nadir FOV locations, slight spatial mismatch between AIRS nadir view FOV location and C3M footprint location
  - Two 16 day periods : Jul 12-Jul27 and Jul28-Aug12 2006

# Retrieval simulation

$$\mathbf{a} = (\mathbf{S}^T \mathbf{S} + \lambda \mathbf{H})^{-1} \mathbf{S}^T \overline{\Delta I},$$

$\Delta I$ : Difference of two 16 days mean nadir view radiances, descending (nighttime) or ascending (daytime)

$\mathbf{S}$ : 10 degree zonal mean kernels (Jacobians)

Skin temperature, 15 layers of T and Q,

3 cloud types (high, mid, and low) of top height, optical thickness, particle size, and cloud fraction

Retrieve 43 variables for 10 degree by 10 degree regions over oceans and average for zonal means

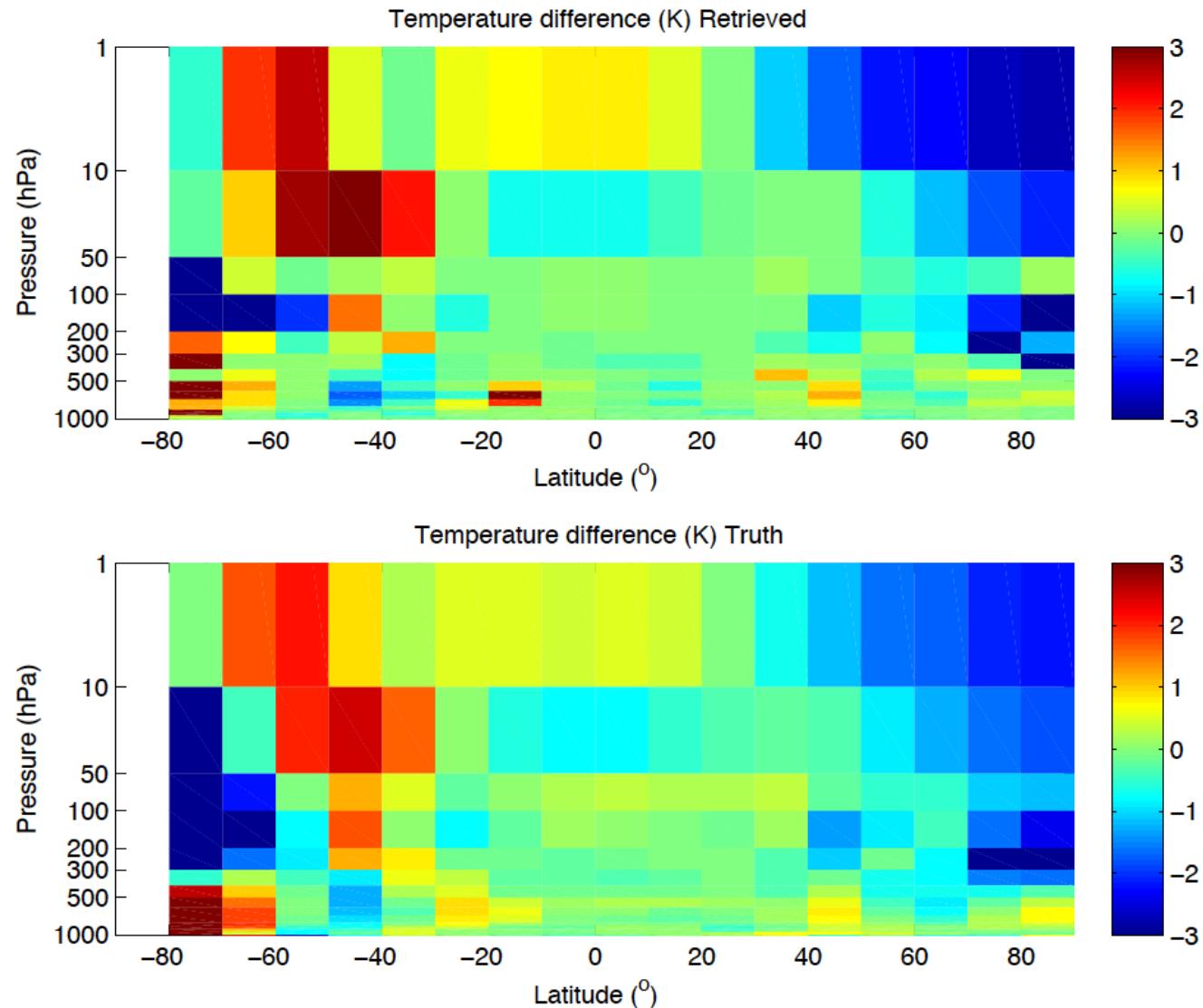
T and Q layer boundary pressure

0.005, 10, 50, 100, 200, 300, 400, 500, 600, 700, 800, 850, 900, 950, 1000, 1100

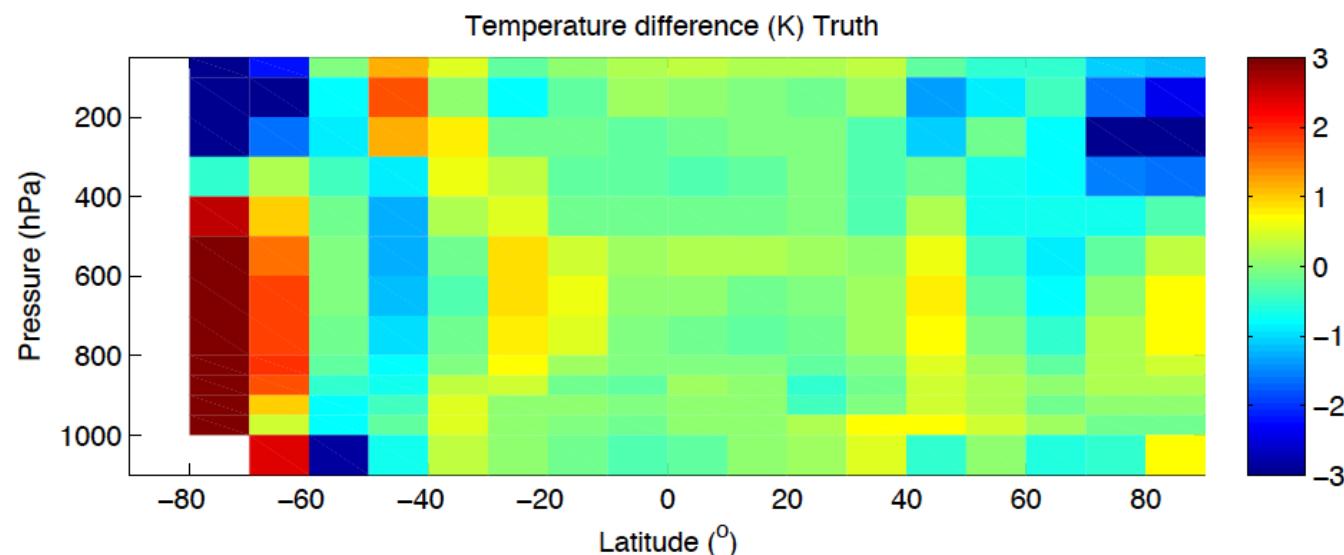
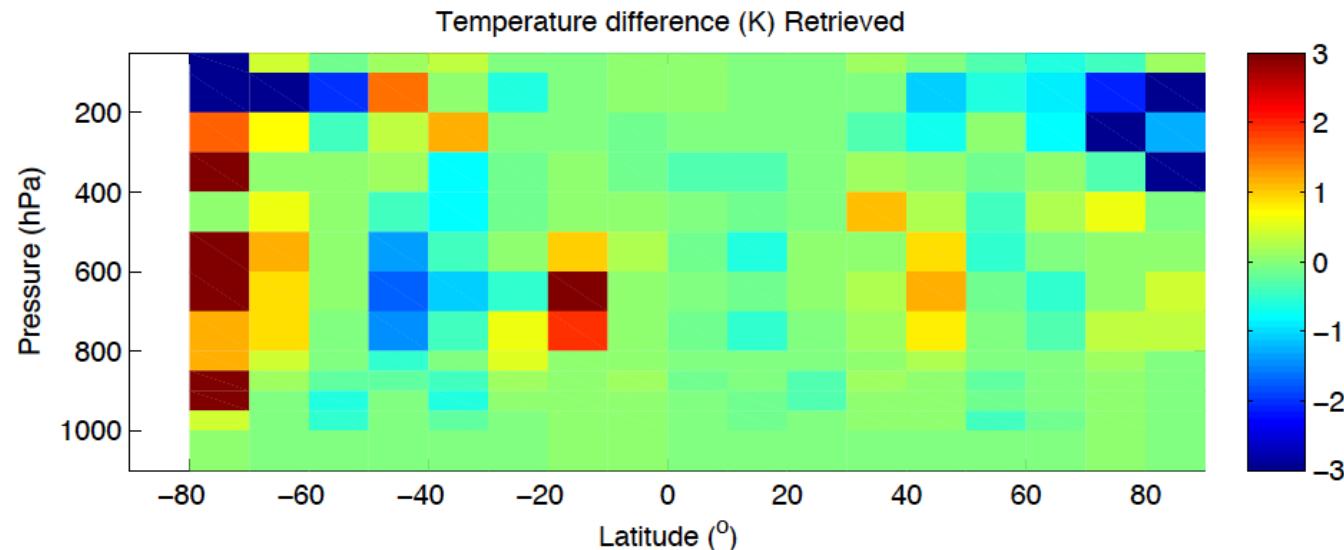
# Retrieval

- Retrieving T, Q and cloud property (fraction, tau, height, Re/De) differences between two 16 day periods (descending (nighttime) and ascending (daytime) orbits separately).
  - Period 1: 20060712 to 20060727
  - Period 2: 20060728 to 20060812
- Focusing on descending (nighttime) over ocean result

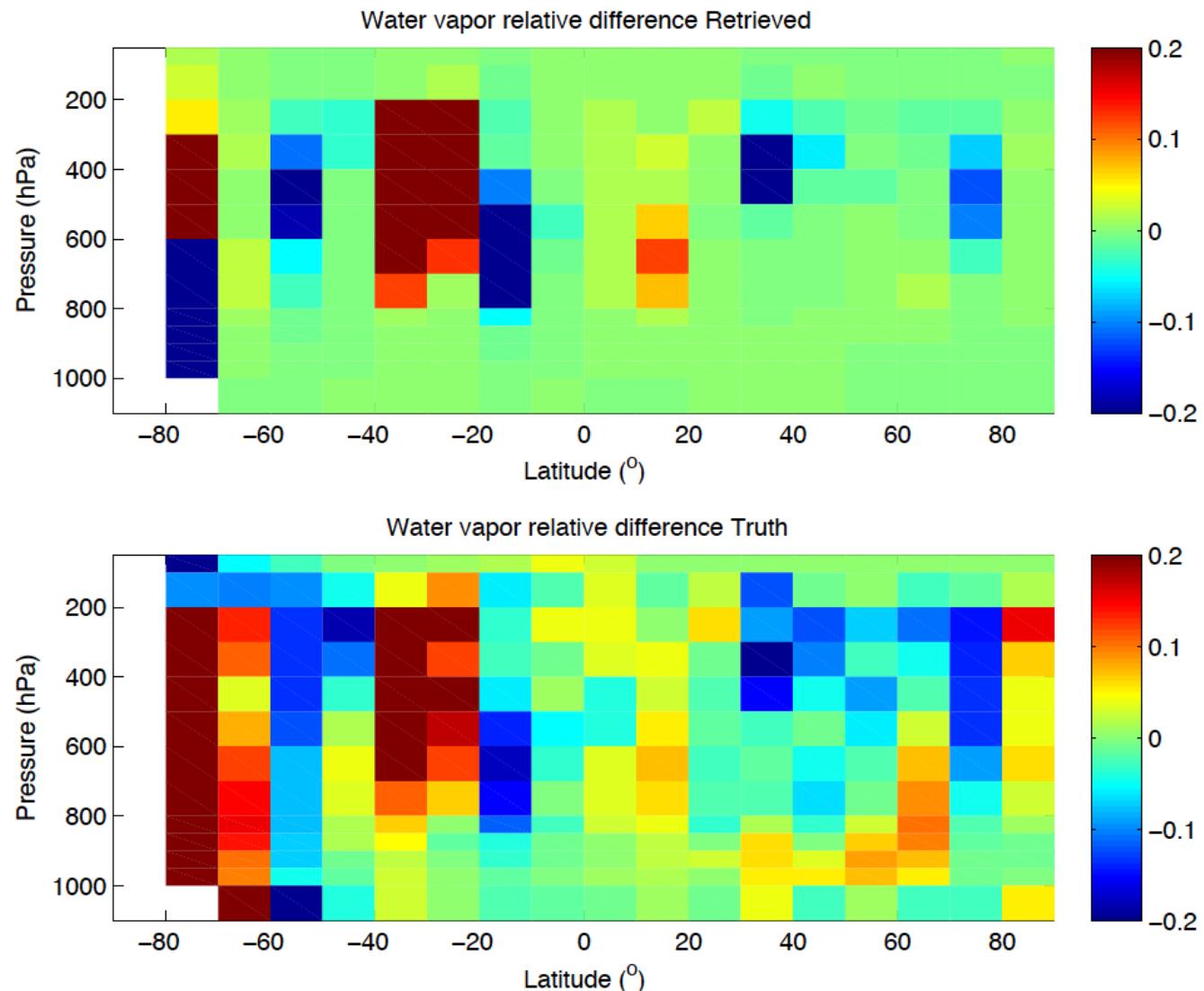
# Nighttime Clear-sky (clouds are taken out)



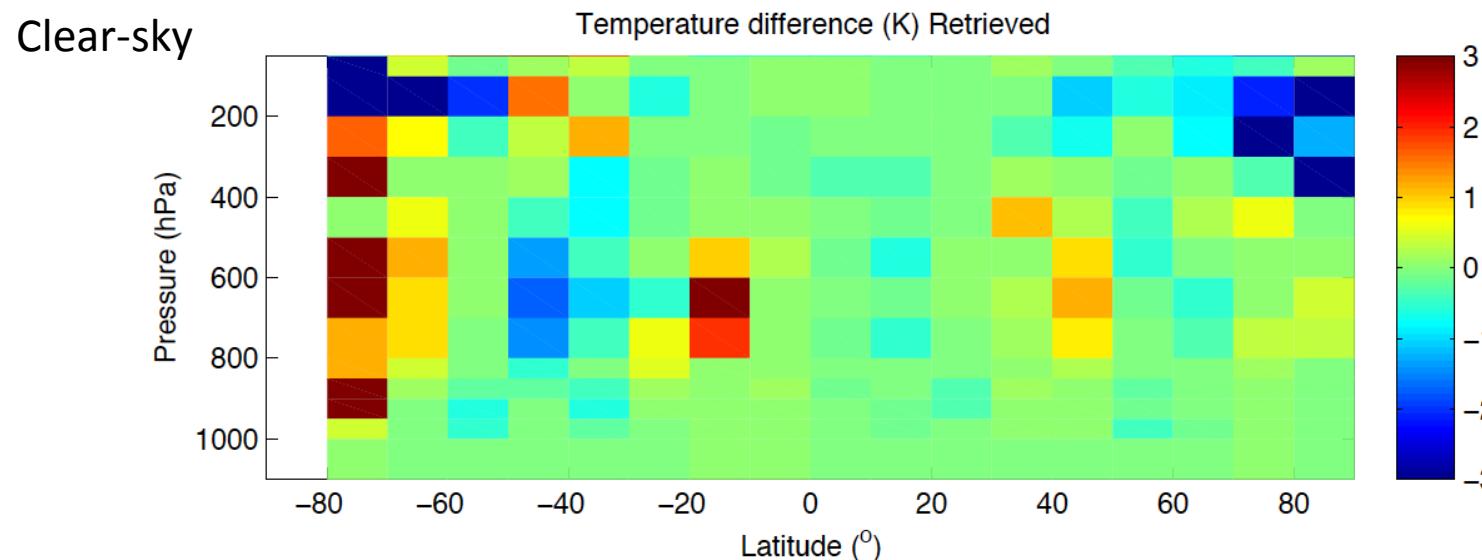
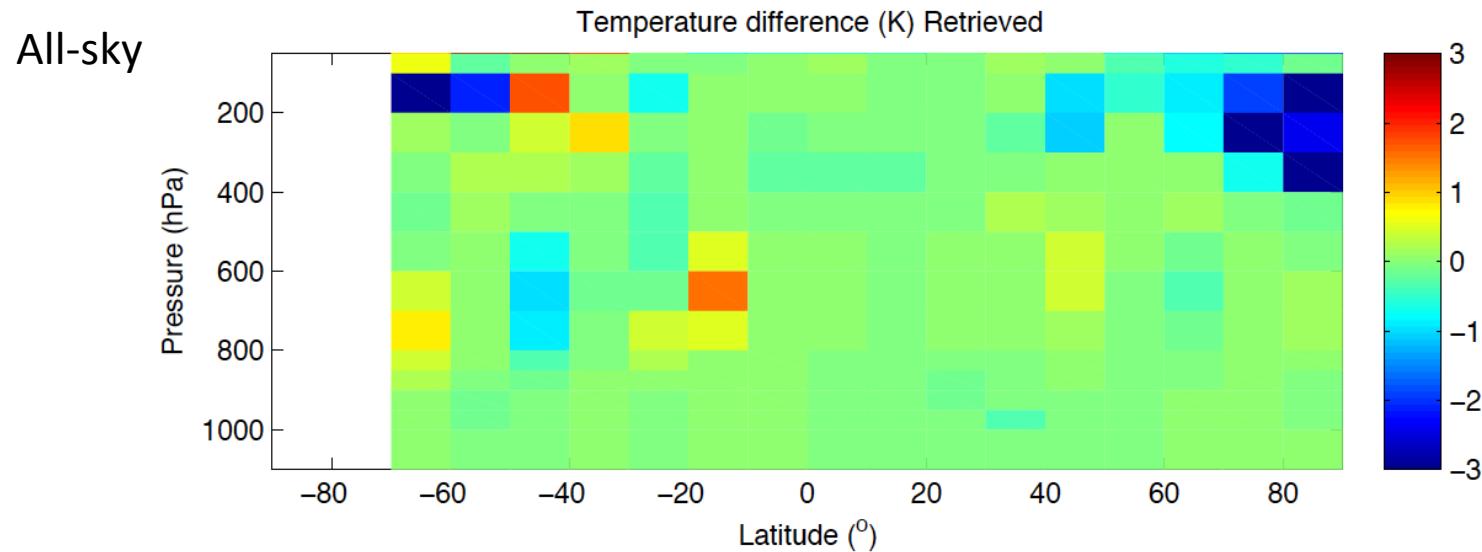
# Clear-sky, tropospheric temperature



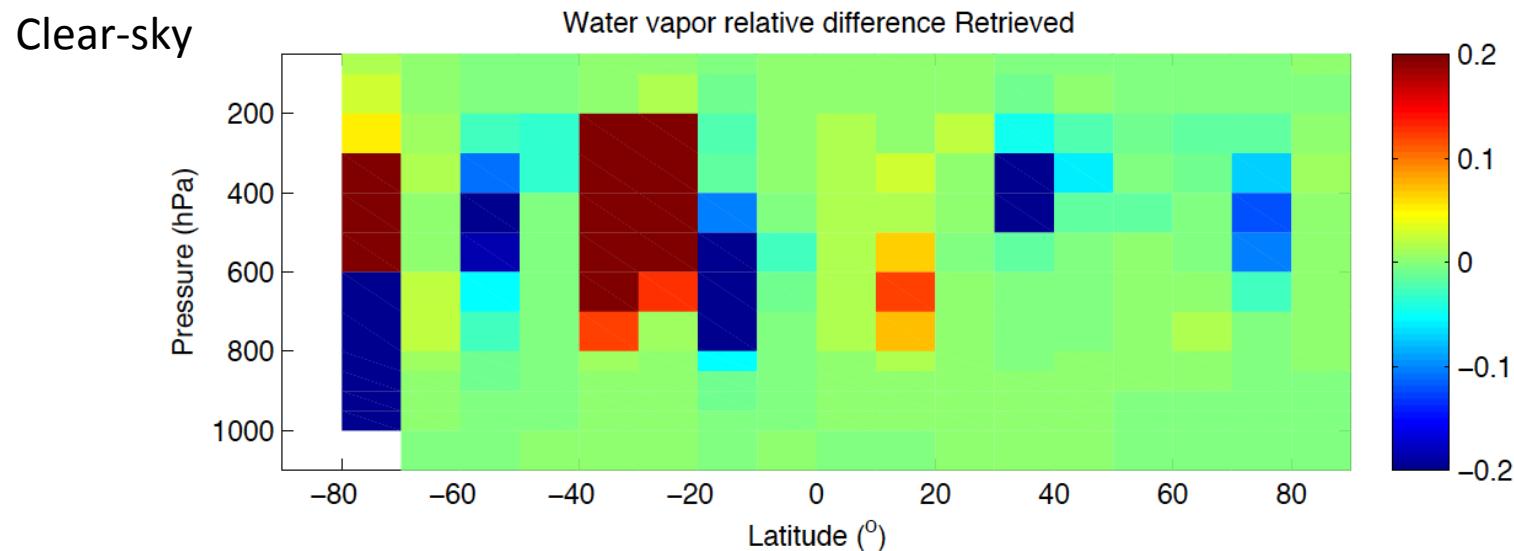
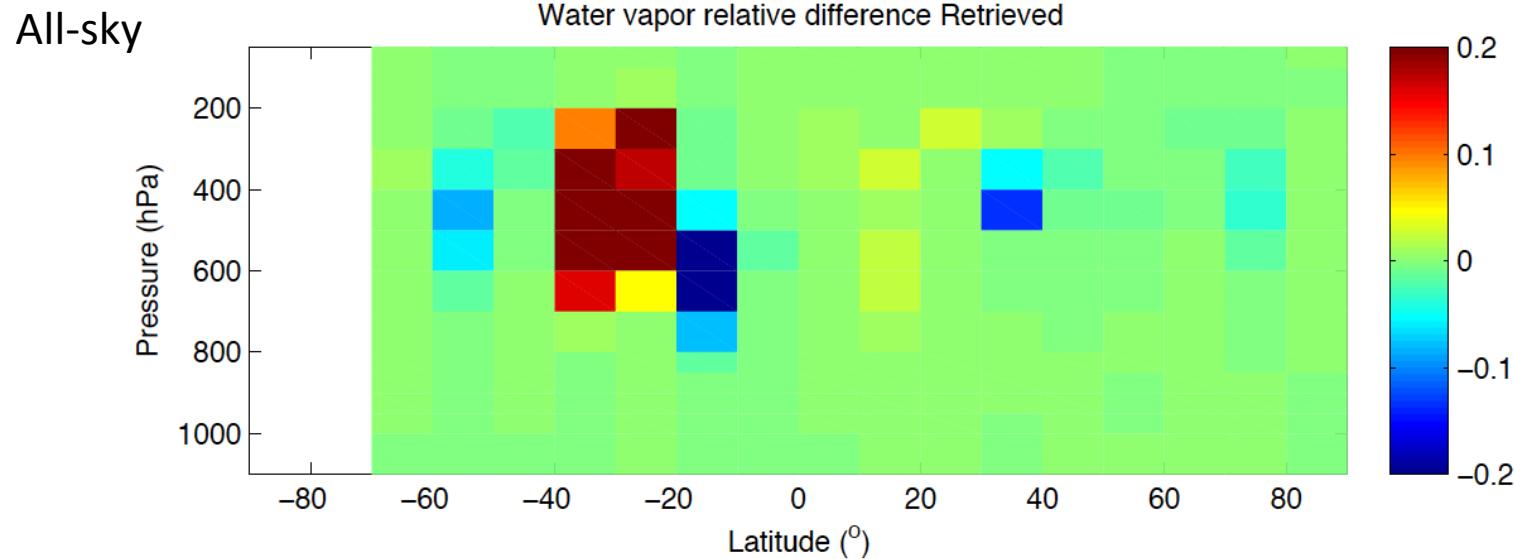
# Clear-sky, water vapor



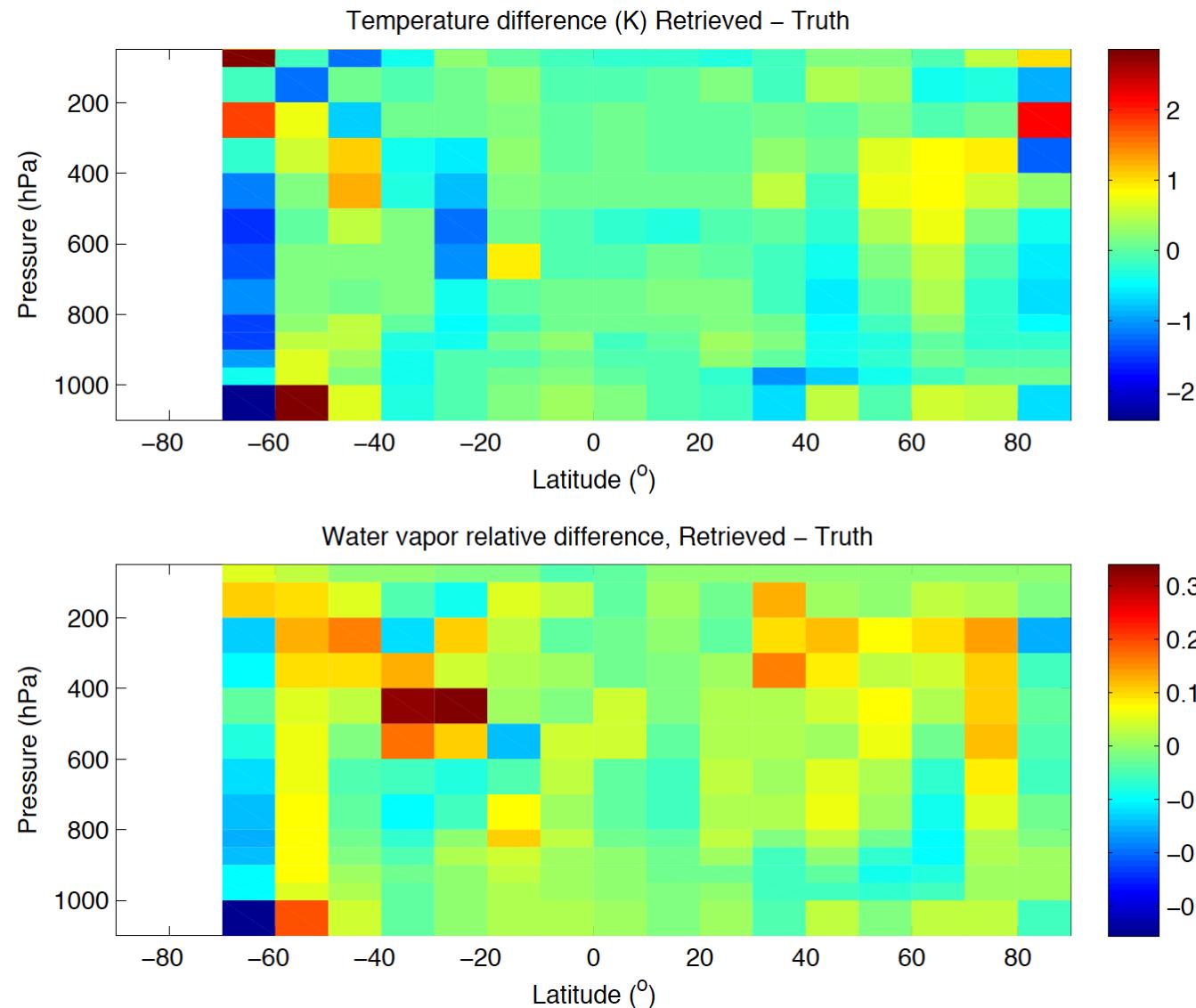
# Clear-sky vs. All-sky, temperature



# Clear-sky vs. All-sky, water vapor

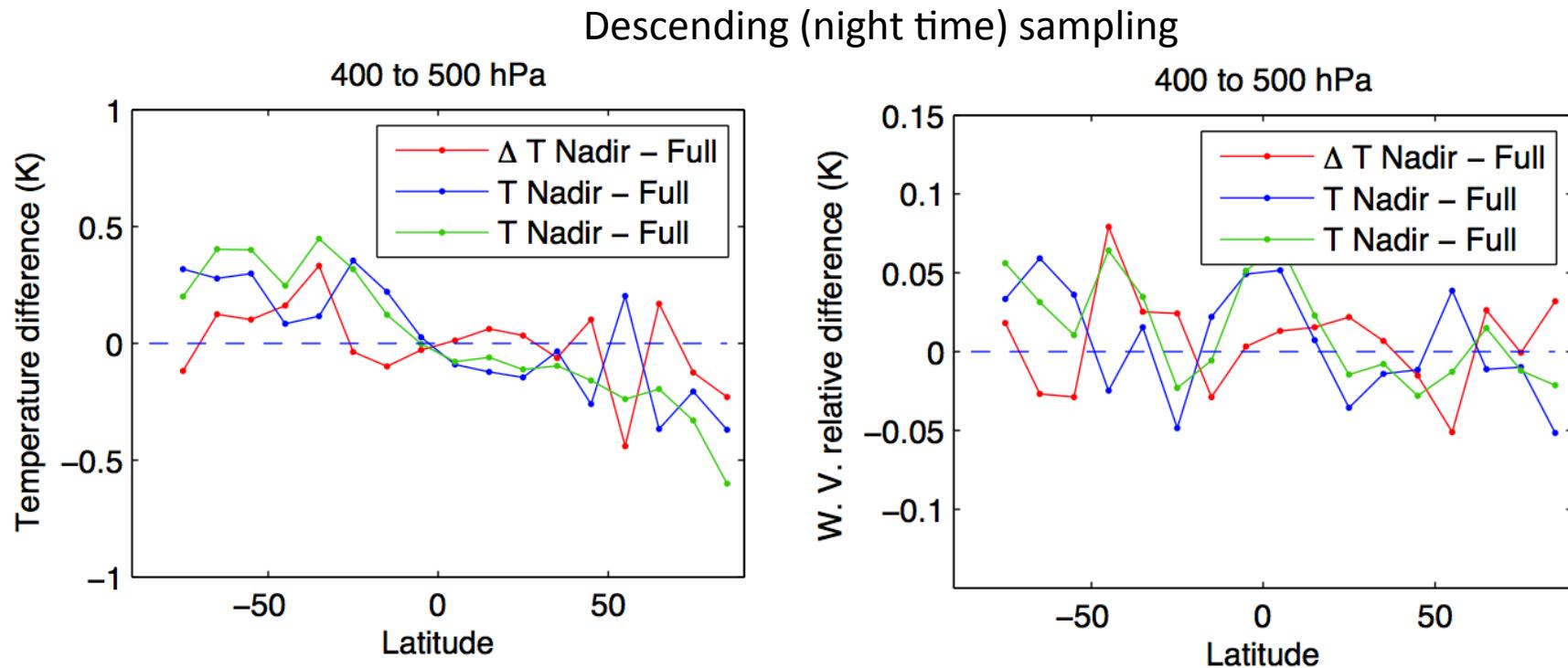


# Retrieved - Truth



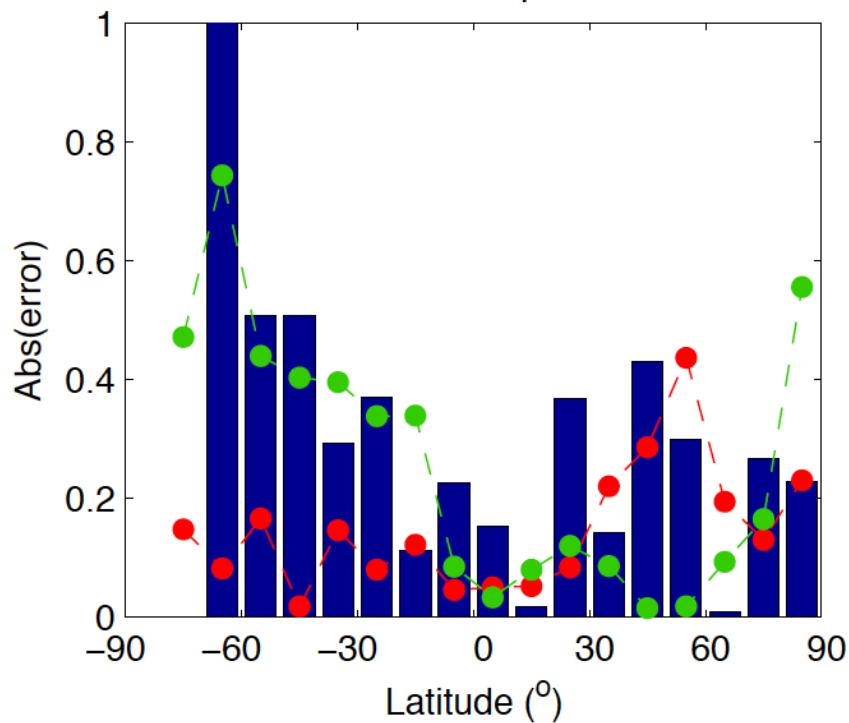
# Retrieval evaluation

- Retrieved  $\Delta T$  and  $\Delta Q$  are evaluated by comparing the retrieval errors and nadir view sampling error
- Nadir view sampling error is determined by comparing with zonal means computed with all grids.

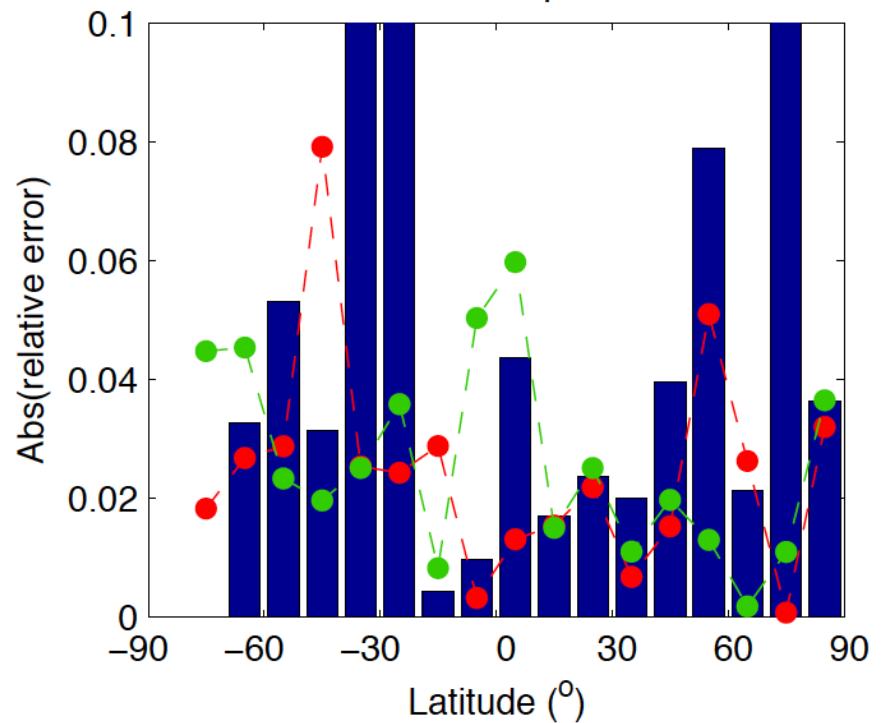


# Retrieval evaluation

850 hPa – 900 hPa Temperature  
(nighttime)



400 hPa – 500 hPa Water vapor amount  
(Nighttime)



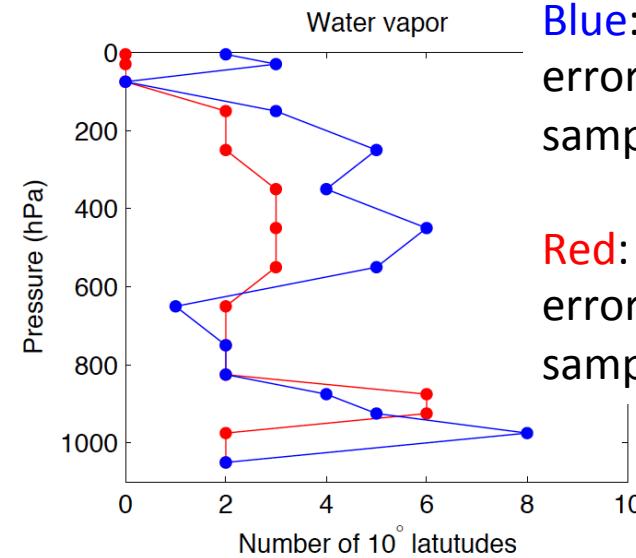
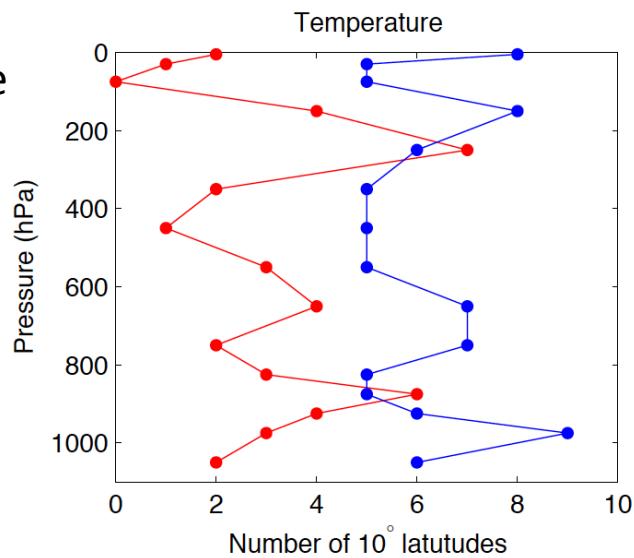
Blue bar: Absolute value of the retrieval error

Red circle: Absolute value of the nadir view sample error (zonal mean period 1 – period 2)

Green circle: Absolute value of the nadir view sample error (zonal mean T and Q)

# Retrieval evaluation

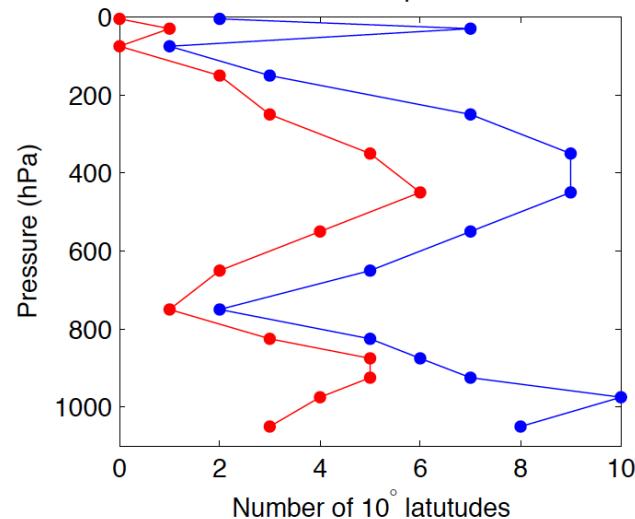
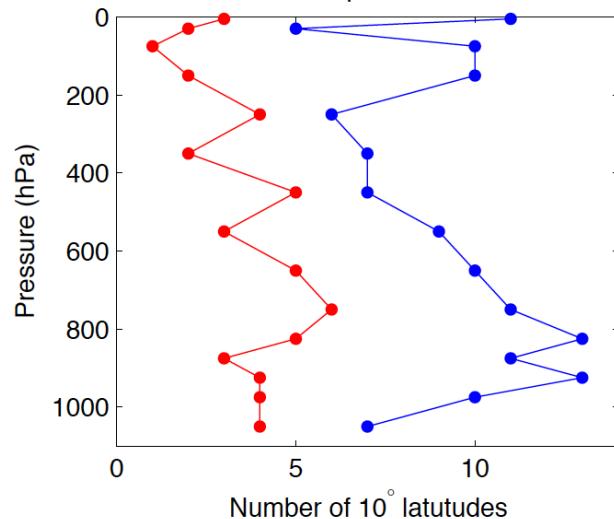
Nighttime



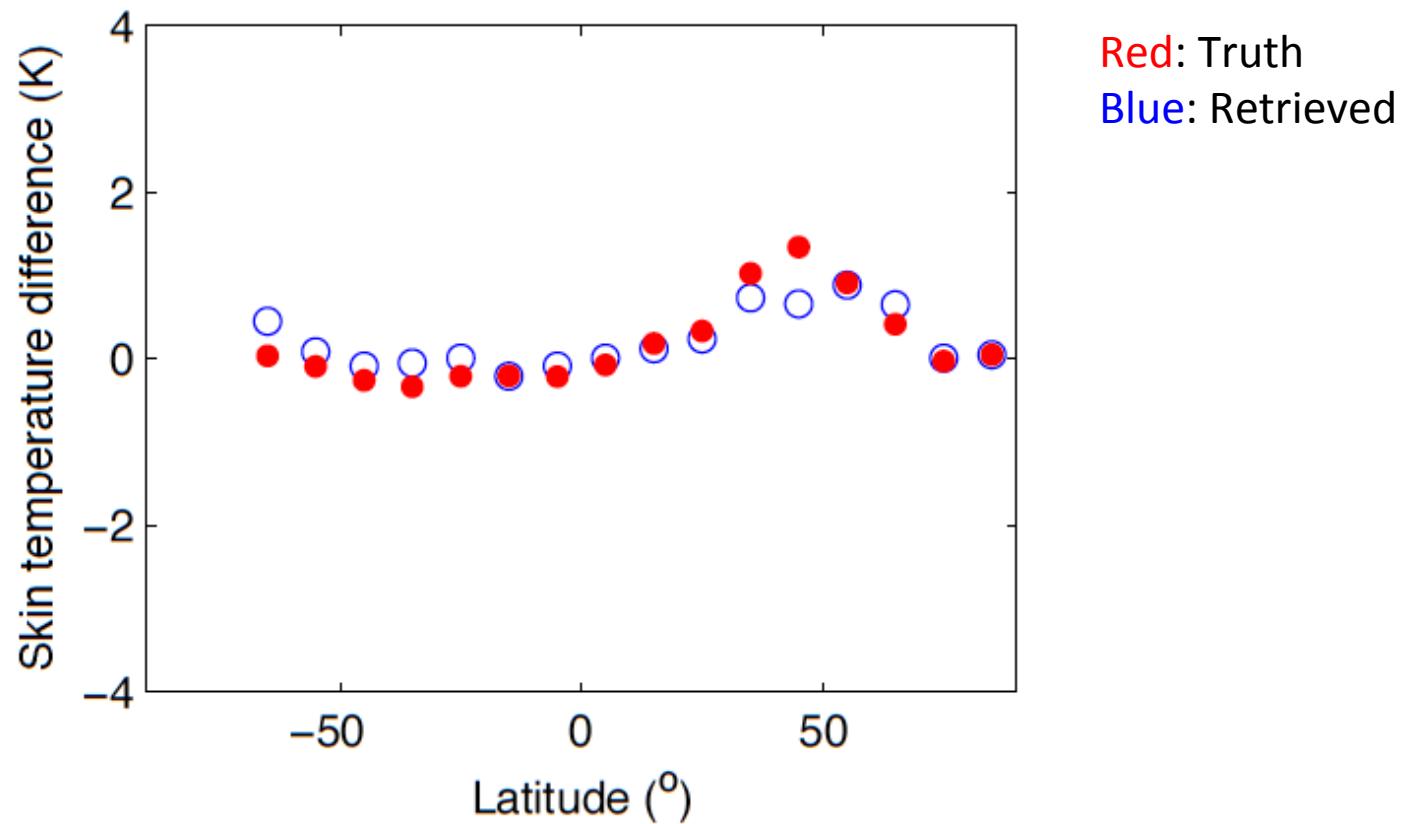
Blue: Retrieval error < T and Q sampling error

Red: retrieval error <  $\Delta T$  and  $\Delta Q$  sampling error

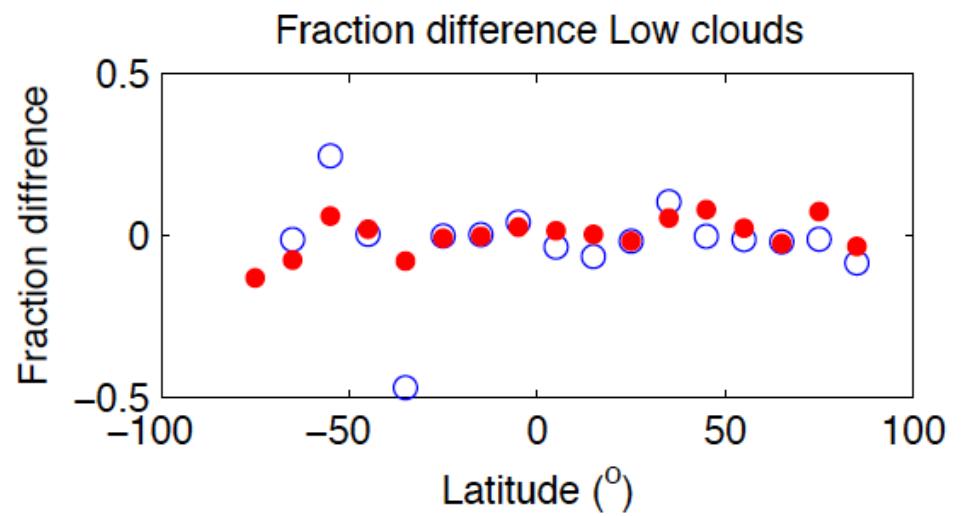
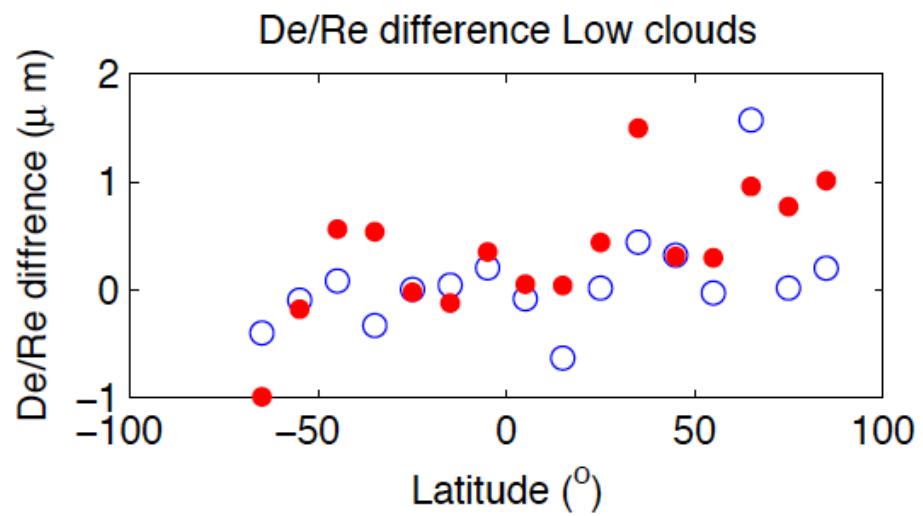
Daytime



# Skin temperature

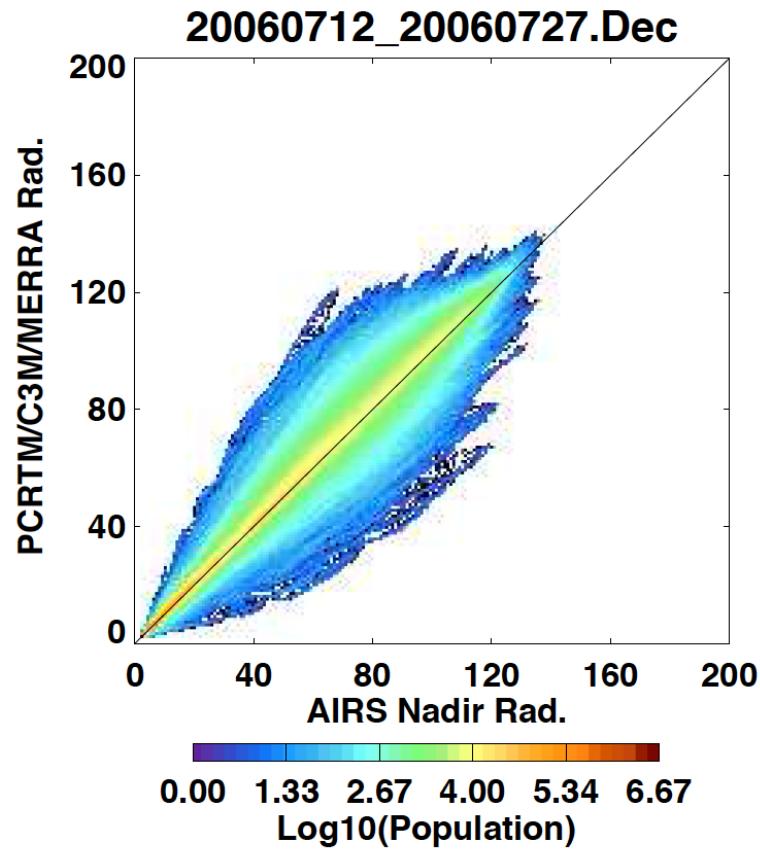


# Cloud properties

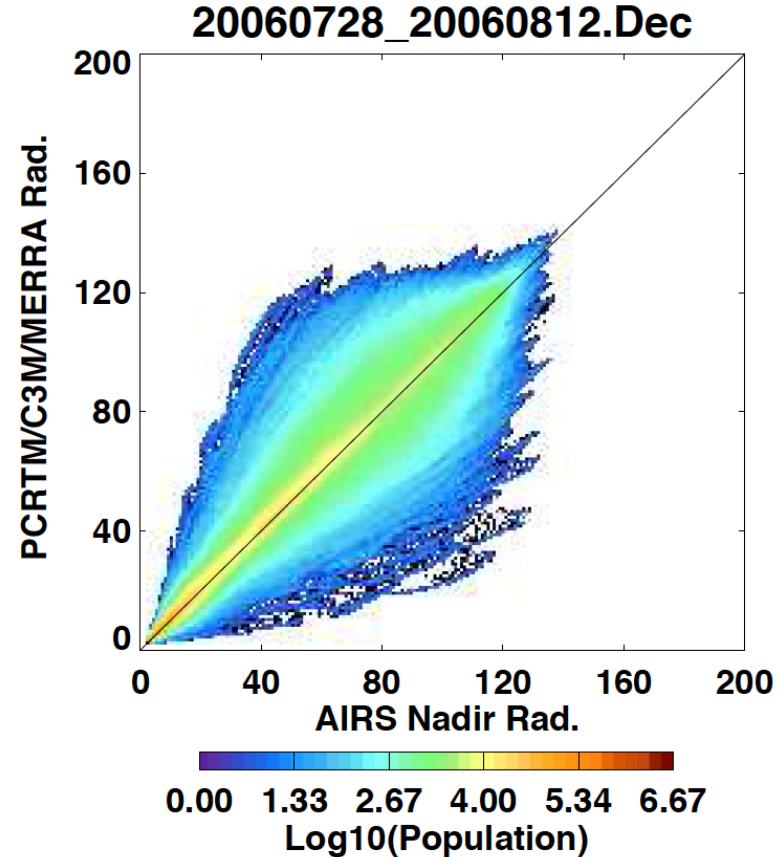


Red: Truth  
Blue: Retrieved

# Modeled vs. Observed (AIRS) radiances

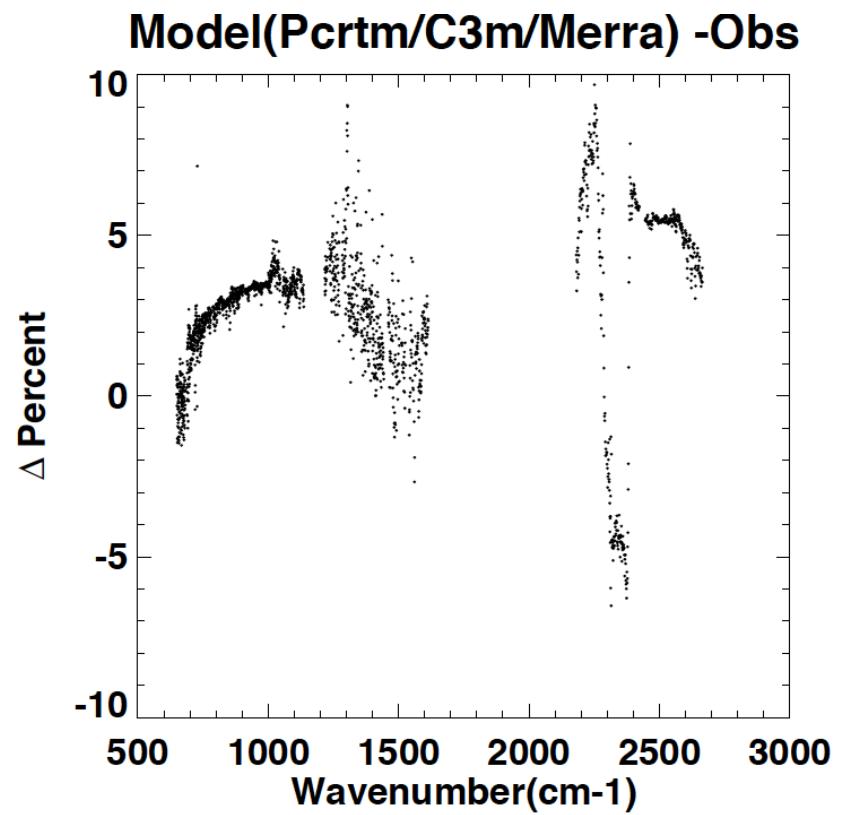
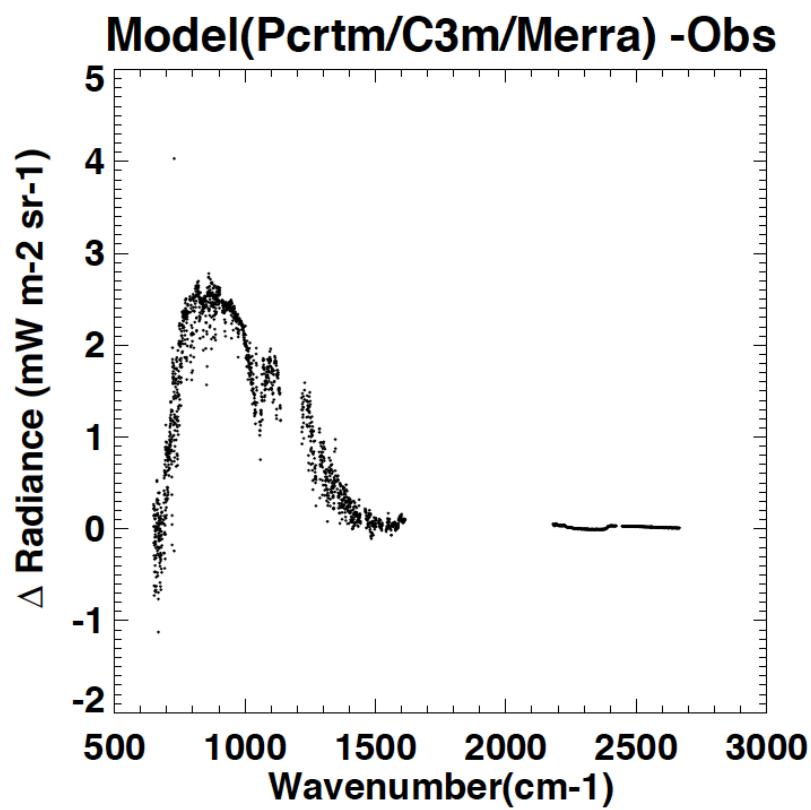


N= 22168893.                          Mean ( StdDev)  
                  AIRS Nadir Rad. 36.35( 34.38)  
                  PCRTM/C3M/MERRA Rad. 37.31( 35.21)  
                         Y-X 0.959( 4.63)  
                         RMS( 4.72).....



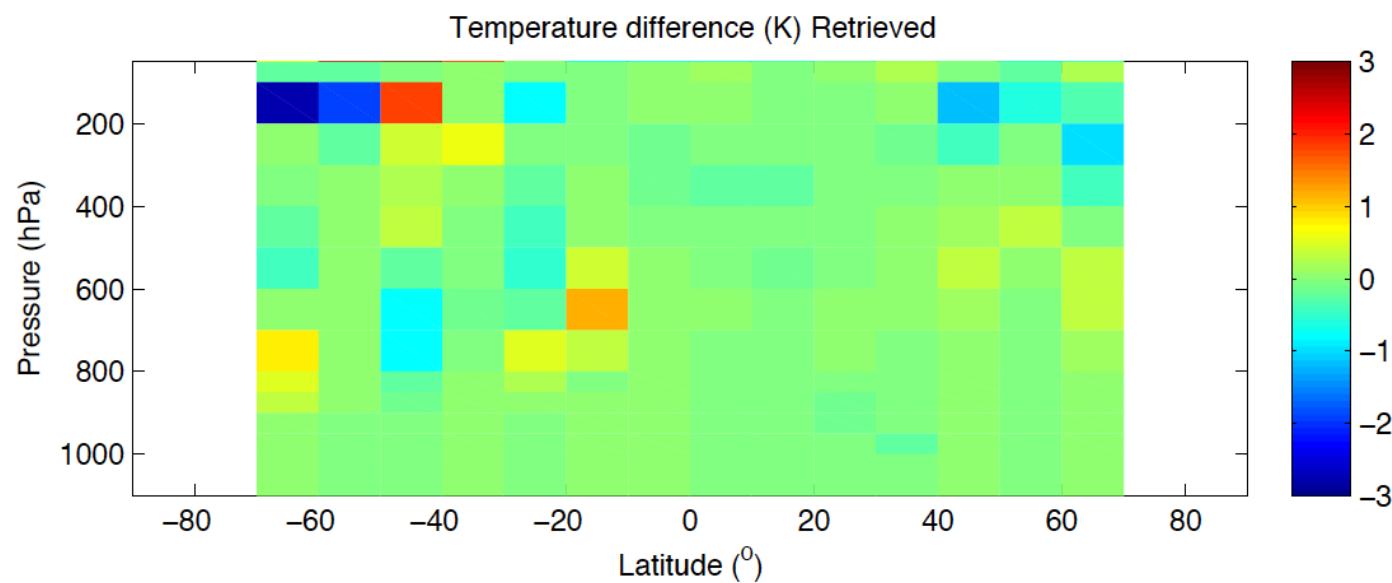
N= 22175136.                          Mean ( StdDev)  
                  AIRS Nadir Rad. 36.36( 34.38)  
                  PCRTM/C3M/MERRA Rad. 37.29( 35.06)  
                         Y-X 0.929( 7.48)  
                         RMS( 7.54).....

# Global mean spectral radiance difference

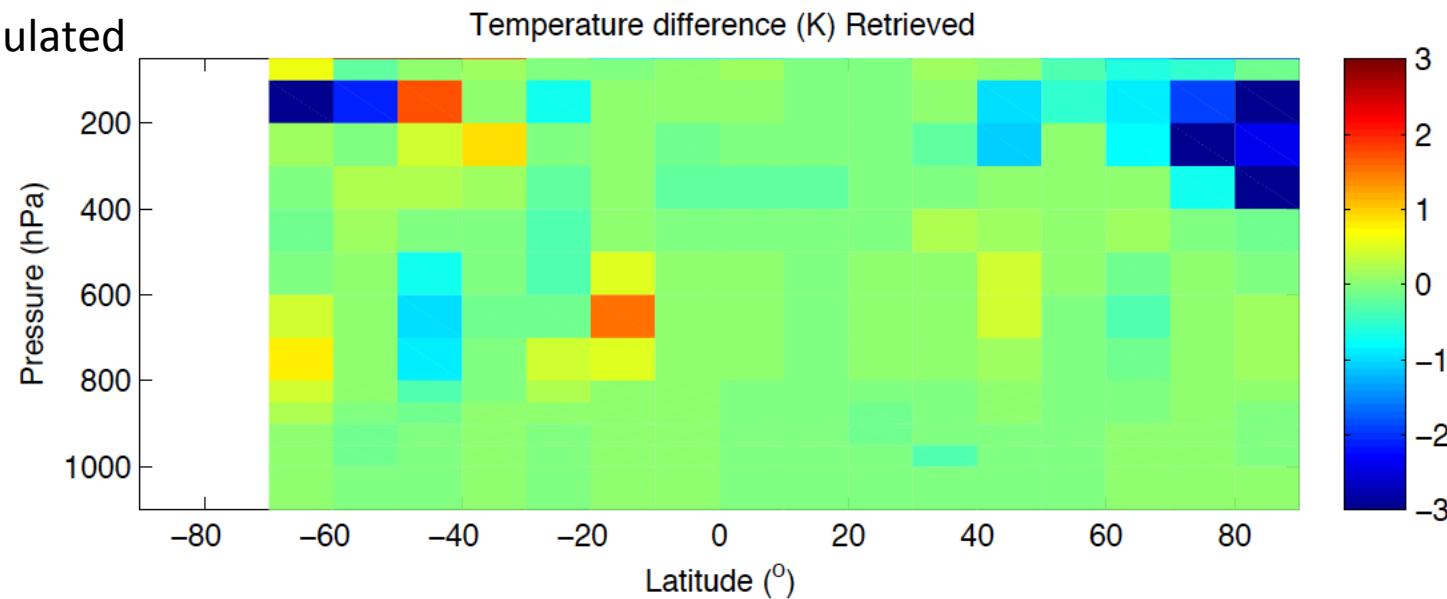


# Retrieval with AIRS nadir view radiances: T

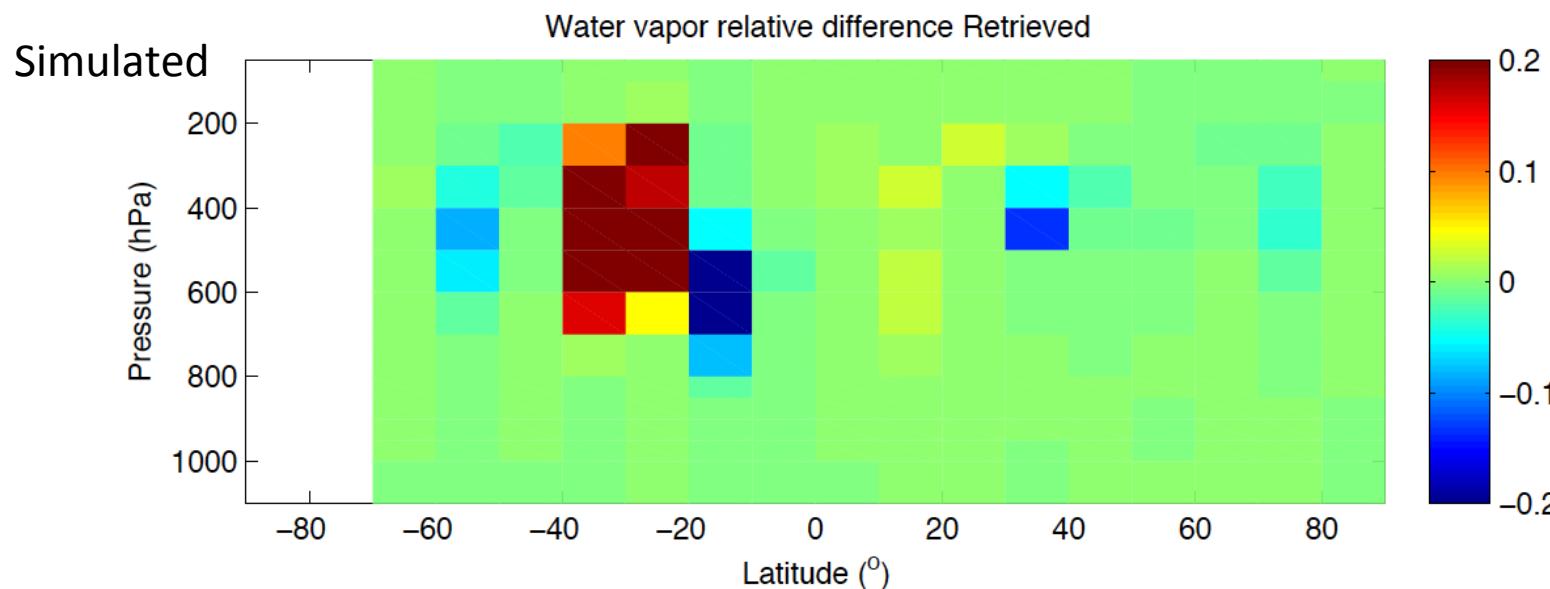
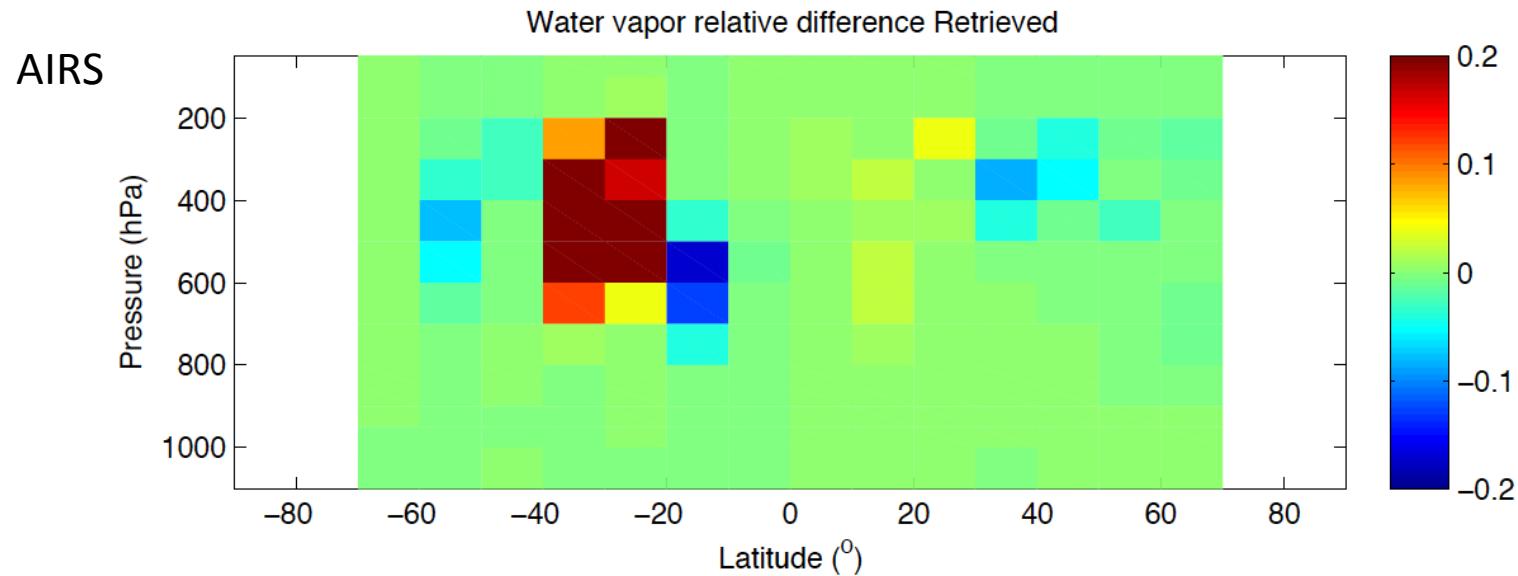
AIRS



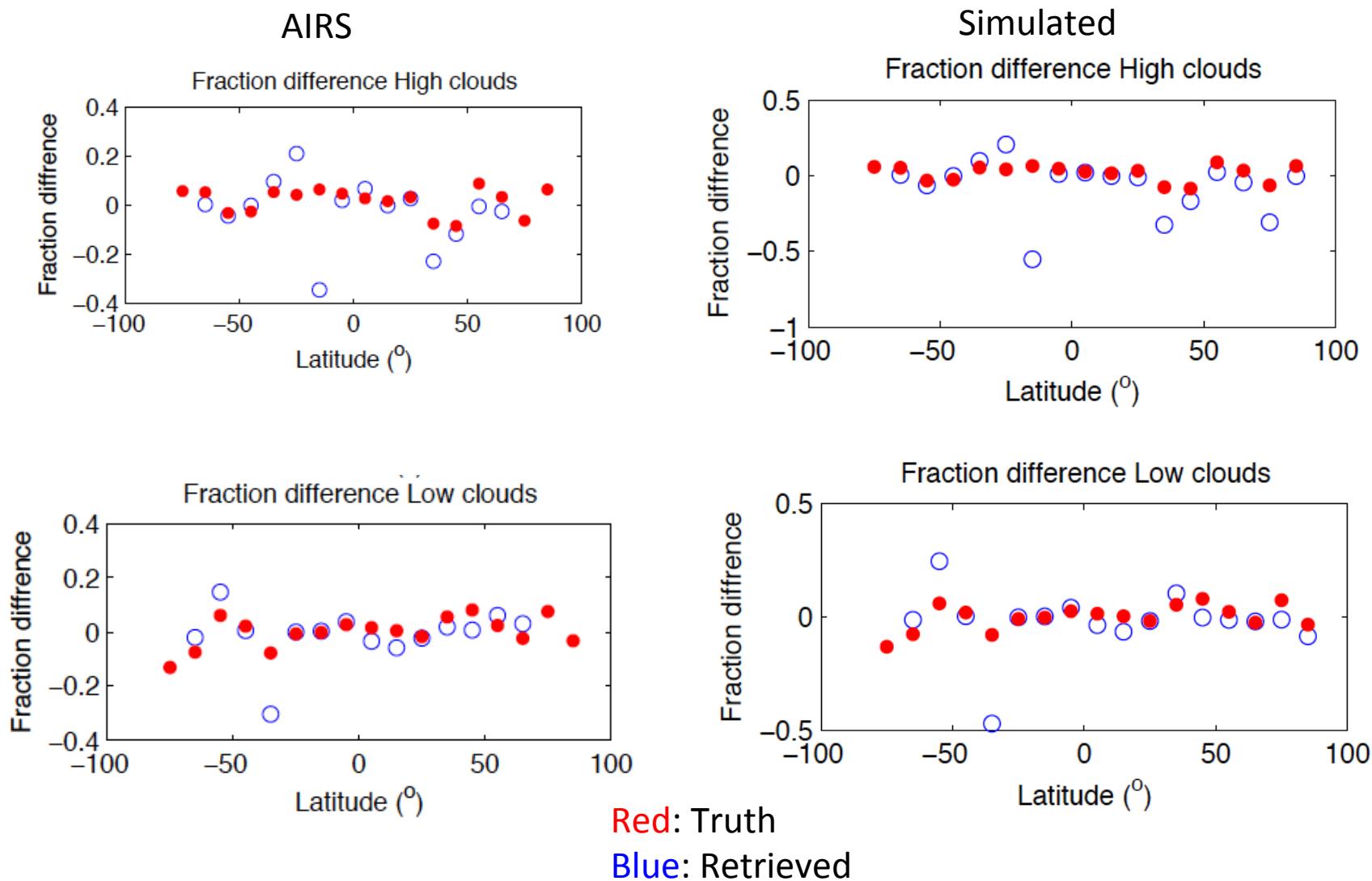
Simulated



# Retrieval with AIRS nadir view radiances: Q



# Low-level cloud fraction



# Summary

- Retrieval of  $\Delta T$  and  $\Delta Q$ , with a high vertical resolution is demonstrated using two sets of 16 day  $10^\circ$  mean nadir view all-sky spectral radiance over ocean using the average-then-retrieve approach.
- 20 to 30% of zonal mean temperature and humidity change retrieval error is smaller than nadir view sampling error.
- Average-then-retrieve approach is also demonstrated with two sets of AIRS 16 day  $10^\circ$  zonal mean spectral radiances. Even though modeled spectral radiances are different from observed spectral radiances up to  $\sim 20\%$  depending on wavenumbers,  $\Delta T$  and  $\Delta Q$  can be derived.
- Retrieval needs to be improved especially changes in cloud properties and humidity at 800 to 700 hPa levels.